



Age Considerations in Four-Corner Arthrodesis and Proximal Row Carpectomy: A Review

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Abstract

Purpose Although indications for four-corner arthrodesis (4CA) and proximal row carpectomy (PRC) are not completely aligned, the surgeon is often tasked with deciding between these options which vary in the surgical technique and complication profile. Patient age is often discussed as a determining factor for treatment; however, outcome data for these procedures are rarely stratified by patient age. Our objective was to perform a systematic review on the age-specific outcomes for 4CA and PRC.

Methods A PubMed database search for 4CA and PRC was performed according to Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines. The inclusion criteria required individual case reporting of patient age, surgical intervention, and appropriate outcome measures. The data were stratified by procedure and by patients older and younger than 45 years.

Results Within the 4CA group, the relative risk for a disabilities of the arm, shoulder, and hand (DASH) score above 30 was 1.94 (95% confidence interval, 1.1–3.67) in patients over 45 years compared with patients under 45 years. Within the PRC group, grip strength as a percentage of the contralateral side was higher in the over 45 age group (mean 75%) compared to the under 45 age group (mean 61%) but did not reach the level of significance.

Conclusion Despite satisfactory results for 4CA in aggregate, the distribution of scores indicates the need for setting expectations when treating younger adult patients with 4CA. The current results demonstrate increased disability based on DASH score following 4CA in patients under 45 years compared with patients over 45 years. Although outcomes were comparable between younger and older adults following PRC, recovery of grip strength may occur less frequently in younger adults.

Level of evidence IV systematic review.

Keywords

- ▶ four corner fusion
- ▶ proximal row carpectomy
- ▶ SLAC
- ▶ SNAC
- ▶ wrist arthritis

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Proximal row carpectomy (PRC) and four-corner arthrodesis (4CA) are considered motion-sparing procedures for various etiologies of wrist arthritis. Although indications for each are not completely aligned, the surgeon is often tasked with deciding between these options which vary in the surgical technique and complication profile. Aggregate reporting has identified nonunion as a common complication following 4CA¹⁻⁴ and limitations in grip strength complicate PRC due to an altered length-tension relationship of the flexors.^{1,5,6}

Patient age continues to be a conundrum in determining the most appropriate treatment in cases of wrist arthritis. Although patient age is often discussed as a determining factor between 4CA and PRC, results are infrequently stratified by age. Wagner et al⁶ reported similar outcomes between 4CA and PRC for a series of patients aged 45 years and under. DiDonna et al⁷ concluded that PRC patients under 35 years had a significantly increased risk of radiocapitate pathology which may translate into worsening clinical outcomes. Whether these findings are representative of the aggregate literature is unknown.

Previous systematic reviews reporting outcomes for 4CA and PRC provided datasets with a mean patient age between 45 and 50 years but the age ranges are widely distributed.^{2,4,8-11} Physiologic aspects of healing and recovery are not uniform across a large age distribution. Thus, treatment decisions should be evaluated within the confines of a more narrow age bracket to provide a template for informed clinical decision-making.

Our objective was to perform a systematic review on the age-specific clinical outcomes for PRC and 4CA. These data intended to determine whether outcomes differed between younger and older age groups and whether 4CA or PRC yielded superior outcomes between these age groups.

Methods

Search Strategy

A PubMed database search was performed on October 05, 2023 according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines. The following search terms were used: “proximal row carpectomy,” “four corner arthrodesis,” “four corner fusion,” “4 corner arthrodesis,” “4 corner fusion,” “scaphoid nonunion advanced collapse,” and “scapholunate advanced collapse.”

Eligibility Criteria

The population, intervention, comparison, and outcome characteristics for eligibility were the following:

- P—adults over the age of 18 years.
- I—treated with PRC and 4CA for all indications.
- C—clinical outcomes between these interventions were compared.
- O—age groups were delineated for outcome comparison.

The inclusion criteria required individual case reporting of patient age, surgical intervention, and appropriate outcome measures.¹² Three or more cases per report were required for inclusion.

Data Collection

The following case data were extracted from each included article: patient age, patient gender, indication for surgical intervention, follow-up term, visual analog score for pain, disabilities of the arm, shoulder, and hand (DASH) score, grip strength expressed as a percentage of the contralateral side, wrist arc of motion, nonunion, hardware removal for 4CA cases, radiographic radiocapitate narrowing for PRC cases, and revision surgery. For outcomes without standardized parameters, a reasonable interpretation of the provided verbiage was made to ensure continuity in aggregation. The lack of revision or removal surgery was not presumed due to the absence of verbiage stating the presence of these secondary procedures. When radiocapitate narrowing was reported using specified criteria, the data were aggregated using a binary protocol of present for moderate/severe arthrosis or partial/complete narrowing and absent for none/minimal.

Data Grouping

The data were stratified by procedure and by patients older than and younger than 45 years. The age of 45 years was chosen to maintain consistency with the prior work by Wagner et al⁶ which compared results between 4CA and PRC in patients under 45 years. Although the Wagner et al article did not provide individual case reporting, it was included in aggregate analysis due to the entirety of the series aligning with the under 45 years age group.

Data Analysis

Clinical outcomes were compiled as means and then compared between groups using the two-sample *t*-test and Fisher's exact test. Due to disparate sample sizes, some data were presented with and without the Wagner et al⁶ article. For DASH scores, results were stratified as scores above and below 30. This score was chosen based on the approximate mean for previous reviews on 4CA and PRC.^{1,4,8,9} The Wagner et al⁶ article was not included in this analysis due to a lack of individual case scores.

Risk of Bias

The Cochrane ROBINS-I (risk of bias in non-randomized studies of interventions) provides the following domains for evaluation: confounding, selection of participants, classification of interventions, deviation from intended interventions, missing data, measurement of outcomes, and selection of reported results.¹³ For all included studies, each domain was graded as low, moderate, or severe risk, and then, a final grade was given which corresponded to the highest level of risk across the domains.

Quality Assessment

The GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) framework provided the following factors for the evaluation of research quality: limitations, inconsistency, indirectness, imprecision, and publication bias.¹⁴ A binary scale for serious limitations was used for each factor across the outcomes of interest.

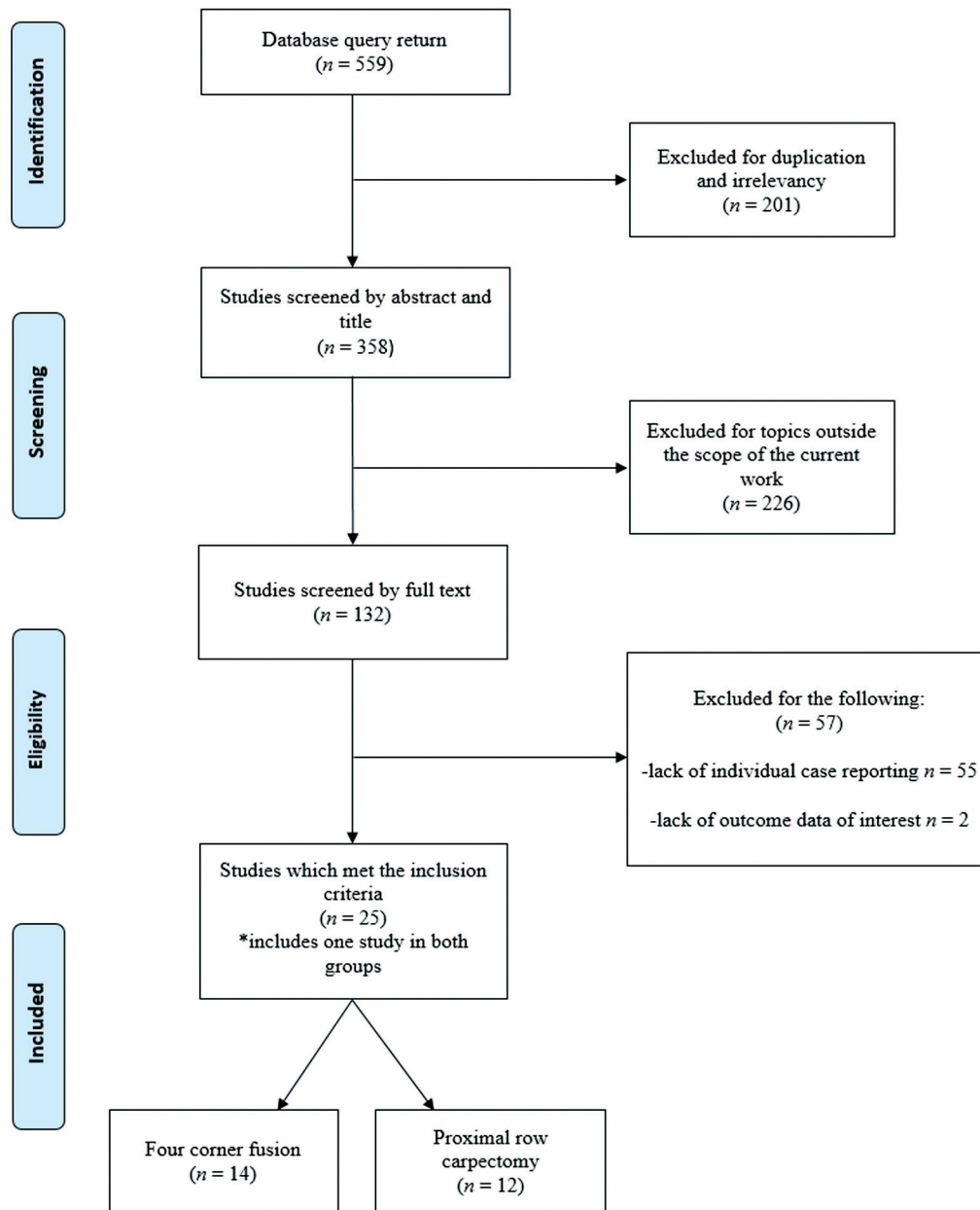


Fig. 1 Flowchart depicting literature search and article retrieval, noting criteria for full text exclusions.

Results

Search Results

Following irrelevant exclusions, 132 articles were screened by full text (► **Fig. 1**). Of those, 55 were excluded due to a lack of individual case reporting. Twenty-five articles met the inclusion criteria with 207 cases in the 4CA group (mean follow-up 50 ± 67 months) and 171 cases in the PRC group (mean follow-up 79 ± 64 months; ► **Table 1**).

Bias and Quality Assessment

There was a moderate risk of bias in at least one domain for all included articles (► **Table 2**). This finding indicates that each study cannot be considered comparable to a well-performed randomized trial.¹³

Within the GRADE framework, articles were grouped based on the reported procedure. There were two articles with the I/II level of evidence—both in the 4CA group (► **Table 3**). There were serious limitations for the risk of bias, sample size, and publication bias for articles in the 4CA and PRC groups.

Clinical Outcomes

Mean DASH scores, grip strength, and postoperative arc of wrist flexion and extension were similar between the 4CA and PRC groups (► **Table 4**). The difference in DASH score between 4CA and PRC and between age groups did not reach the established minimal clinically important difference.¹⁵

Within the 4CA group, the relative risk for a DASH score above 30 was 1.94 (95% CI, 1.1–3.67) in patients over 45 years compared with patients under 45 years (► **Fig. 2**). Within the

Table 1 Cochrane risk of bias ROBINS-I (risk of bias in nonrandomized studies of interventions) for review of four corner arthrodesis and proximal row carpectomy.

Study	Confounding	Selection of participants	Classification of interventions	Deviation from intended interventions	Missing data	Measurement of outcomes	Selection of reported result	Overall bias
Four corner arthrodesis								
Gupta, 2010	?	+	+	+	?	+	?	?
Mantovani, 2010	?	?	+	+	+	+	+	?
Xu, 2013	?	+	+	+	?	+	?	?
Eid, 2015	?	+	+	+	+	+	?	?
Chaudhry, 2016	?	?	+	+	?	+	+	?
Shintani, 2016	?	?	+	+	+	+	?	?
Traverso et al 2017 ²⁰	?	?	+	+	?	+	+	?
Elgammal, 2018	?	?	+	+	+	+	+	?
Mamede, 2018	?	?	+	+	+	+	+	?
Vihanto, 2019	+	?	+	+	+	+	?	?
Zenke, 2021	?	?	+	+	+	+	?	?
Corain, 2022	?	?	+	+	+	+	?	?
Ghargozloo, 2022	?	?	+	+	+	+	?	?
Proximal row carpectomy								
Nagelvoort, 2002	+	?	+	+	?	+	?	?
Jebson, 2003	+	?	+	+	?	+	+	?
van Kooten, 2005	?	+	?	+	+	+	?	?
Tang, 2007	?	?	+	+	+	+	?	?
Croog, 2008	?	+	+	+	?	+	+	?
Lumsden, 2008	+	+	+	+	?	+	?	?
Streich, 2008	+	+	+	+	?	+	+	?
Edouard, 2010	+	?	+	+	+	+	?	?
Pogliacomini, 2014	?	?	+	+	?	+	?	?
Mandarano-Filho, 2015	?	?	+	+	?	+	?	?
Wagner et al 2017 ⁶	?	?	+	+	+	+	+	?
Lee, 2021	?	?	+	+	+	+	?	?

Note: + indicates low risk of bias, ? indicates moderate risk, and - indicates serious risk.

4CA group, the rate of nonunion was similar between the age groups. There was an increased rate of revision in the under 45 age group (7.8%) compared with the over 45 age group (2.3%) which was significant ($p = 0.041$) with the inclusion of the Wagner et al study to the under 45 age group (13.7%; ► **Table 5**).

Within the PRC group, grip strength as a percentage of the contralateral side was higher in the over 45 age group (mean 75%) compared with the under 45 age group (mean 61%) but did not reach the level of significance. Within the PRC group, the rate of radiocarpitate joint disease was similar between

Table 2 An adapted Grading of Recommendations Assessment, Development and Evaluation summarization for review of four corner arthrodesis and proximal row carpectomy

	Limitations		Inconsistency	Indirectness	Imprecision	Publication bias
Procedure groups	I/II LoE ^a	Risk of bias	Outcomes	Outcomes	Sample size	Outcomes
Four corner arthrodesis	2/14 ^a	✓	X	X	✓	✓
Proximal row carpectomy	0/12 ^a	✓	X	X	✓	✓

^aOne study is included in both groups: ✓—serious limitations, X—no serious limitations.

Table 3 Case characteristics for included studies reporting on four corner arthrodesis and proximal row carpectomy stratified into age groups

Patient age	Studies	Cases	Age (y) ^a	Gender (m) ^a	Follow up term (mo) ^a
Four corner arthrodesis					
Under 45 y	14	143	36.9	90%	47.5
Over 45 y	10	64	60.6	80%	52.9
Proximal row carpectomy					
Under 45 y	11	112	37.1	91%	95.3
Over 45 y	10	59	58.8	70%	78.1

^aAge in years, gender in male, follow-up in months.

Table 4 Clinical outcomes for included studies reporting on four corner arthrodesis and proximal row carpectomy stratified into age groups

Patient age	DASH ^a	Grip strength (% cl) ^a	Arc of motion (preoperative) ^a	Arc of motion (postoperative) ^a
Four corner arthrodesis				
Under 45 y	21.5	74%	78 degree	67 degree
Over 45 y	20.2	70%	85 degree	76 degree
Significance	$p = 0.84$	$p = 0.44$	$p = 0.76$	$p = 0.39$
Proximal row carpectomy				
Under 45 y	26.4	61%	65 degree	80 degree
Over 45 y	22.8	75%	67 degree	71 degree
Significance	$p = 0.59$	$p = 0.17$	$p = 0.93$	$p = 0.32$

Abbreviation: DASH, disabilities of the arm, shoulder, and hand.

^aDisabilities of the arm, shoulder, and hand score, grip strength as a percentage of the contralateral side, wrist flexion/extension arc of motion measured preoperative and postoperative.

the age groups, at a mean follow-up of 87 months in the over 45 age group (43%) and 105 (21%) and 115 (28%) months in the under 45 age group.

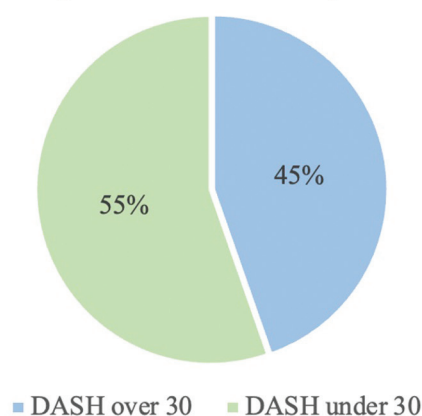
Discussion

Although the mean DASH scores following 4CA are comparable between patients under and over 45 years, the distribution of scores is conspicuous. The current results demonstrate an increased risk of disability based on DASH score following 4CA in patients under 45 years compared to patients over 45 years. There was a nearly twofold increase in risk of a DASH score above 30 in the younger adult group following 4CA. This finding indicates an increased risk of continued pain and dysfunction in adults under 45 years who are treated with 4CA compared with adults over 45 years.

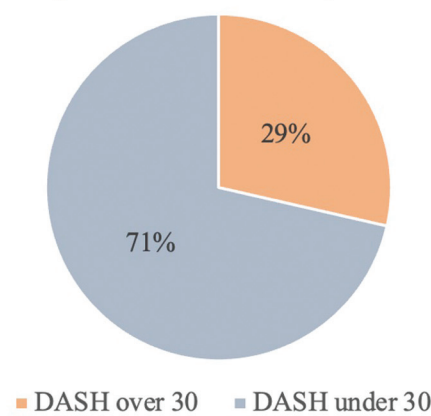
Following PRC, patients over 45 years had greater recovery of grip strength compared with patients under 45 years. This may be explained by a general decline in strength with advancing age. Thus, the loss of strength may be more impactful and demonstrable in younger adults. Grip strength is a commonly reported clinical outcome following the treatment of wrist arthritis. Results between 4CA and PRC are conflicting across the literature with reasonable postu-

lates for both procedures yielding superiority of grip strength. Laronde et al¹⁶ reported superior grip strength in PRC compared with 4CA despite a significant loss in carpal height in the PRC group. The review by Saltzman et al¹ found significantly superior grip strength following 4CA compared with PRC. Conversely, the review by Amer et al³ reported significantly greater grip strength in PRC patients compared with 4CA patients. The lack of uniformity between results for grip strength following 4CA and PRC may be explained by the findings of Nichols et al⁵ which described alterations in muscle moment arms following both procedures. PRC yielded a flexion bias and 4CA, a radial deviation bias. With the understanding that grip strength may be optimized in wrist extension and ulnar deviation, the planar changes in muscle moment arms may explain why reduced grip strength may follow both procedures.

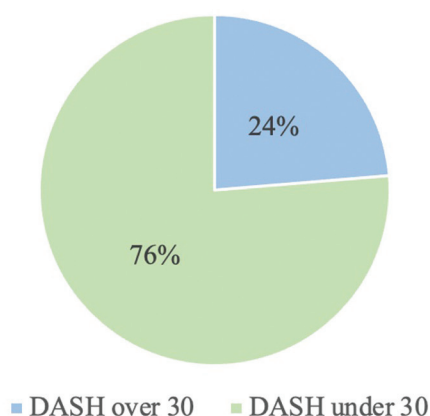
Following PRC, pathological changes to the radiocarpitate joint may be due to nonanatomic loading patterns and a mismatched radius of curvature between the capitate and lunate fossa. The PRC review by Chim and Moran¹¹ determined that a high rate of radiographic radiocarpitate arthrosis did not yield clinically impactful findings at more than 10 years of follow-up. This finding is consistent with Wagner et al¹⁷ who reported 45% of moderate-to-severe radiocarpitate arthrosis following PRC at a mean follow-up of 13 years.

4CA in patients under 45 years of age

■ DASH over 30 ■ DASH under 30

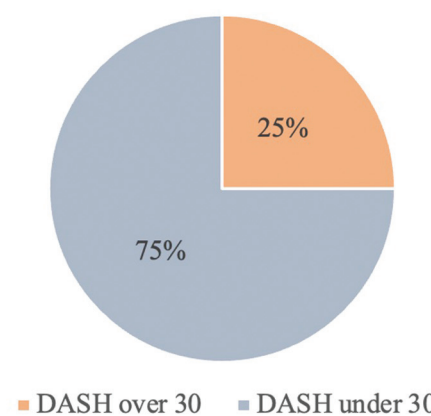
PRC in patients under 45 years of age

■ DASH over 30 ■ DASH under 30

4CA in patients over 45 years of age

■ DASH over 30 ■ DASH under 30

4CA - four corner arthrodesis

PRC in patients over 45 years of age

■ DASH over 30 ■ DASH under 30

PRC - proximal row carpectomy

Fig. 2 Graphical comparison of DASH scores distribution between younger and older adult patients following four corner arthrodesis and proximal row carpectomy.

Table 5 Complications for included studies reporting on four corner arthrodesis and proximal row carpectomy stratified into age groups

Patient age	Nonunion	Radiocapitate narrowing	Revision
Four corner arthrodesis			
Under 45 y	6%/8.2%		7.8%/13.7%
Over 45 y	3.1%		2.3%
Significance	$p = 0.70/0.35$		$p = 0.37/0.041$
Proximal row carpectomy			
Under 45 y		21%/28%	11.4%/17.8%
Over 45 y		43%	IR
Significance		$p = 0.007/0.11$	

Abbreviation: IR, insufficient reporting.

Note: Nonunion and revision reported without/with the Wagner et al study, radiographic evidence of radiocapitate pathology reported with 5 year/10 year results from Wagner et al study.

Using four-dimensional scanning in PRC patients at a mean follow-up of 7.3 years, Peymani et al¹⁸ described increased radiocapitate contact area and capitate remodeling. This is indicative of the adaptive response which contributes to favorable outcomes despite a nonanatomic result of PRC. Although the current findings show comparable rates of advanced radiocapitate pathology between younger and older adults following PRC, continued monitoring in younger adults may be advised.

Prior reports have identified patient age as an important consideration for treatment decisions involving 4CA and PRC. Wagner et al⁶ provided one of the few reports for the performance of 4CA and PRC in younger adults. Their series spanned a spectrum of disease severity and indications, with few exclusions. At a mean follow-up of 11 years for the 4CA group and 18 years for the PRC group, there were similar rates of radiographic arthrosis in both groups, and motion trended toward superior for the PRC group. Further, the same group provided a narrative review of 4CA and PRC in young

patients which highlighted the lack of definitive data in support of either of these procedures.¹⁹ Traverso et al²⁰ reported high patient satisfaction and function at more than 10 years follow-up and noted the durability of 4CA in younger adults as 33% of the series were aged 45 years or under at the time of the index procedure. Despite 27% of 4CA cases having advanced radiolunate space narrowing, the authors reported a mean DASH of 7.8, revision to wrist fusion of 6.7%, and zero cases of nonunion. The current findings indicate an increased risk of revision in younger adults compared with older adults following 4CA.

Important considerations have been identified to guide surgeons when evaluating 4CA and PRC in younger adults. The review by the Wagner group noted that clinical satisfaction following 4CA may be predicated on bony union.¹⁹ Thus, activities such as smoking which increases the risk of nonunion must be considered.²¹ Additionally, job or lifestyle activities which require a greater range of motion may indicate a preference for the motion preservation of PRC. However, motion discrepancies between PRC and 4CA may not be as functionally evident in younger adults due to adaptive capacity. It is reasonable to anticipate if not expect adaptations in adjacent joints to yield improved function over time. Further, the concern for radiocapitate arthrosis following PRC is certainly more warranted in younger adults. In totality, the surgeon must evaluate patient specifics including age and have a complete understanding of the mechanics involved in 4CA and PRC when indicating these procedures.

We acknowledge existent limitations, primarily those that are inherent to amalgamating the work of others. Errors and biases from the included studies weaken the current work. Further, when aggregating clinical outcomes, there is the potential for reporting and interpretation errors. DASH and QuickDASH differ in the number of questions which can impact the absolute value of the score. These metrics are often reported interchangeably which can confound aggregate reporting. Additionally, there was heterogeneity in the verbiage used to report radiocapitate narrowing. The included studies infrequently identified the specific cases which required revision; thus, the current findings for revision should be interpreted as incomplete. However, the noted trend of increased revision in younger adults following 4CA is consistent with prior literature and supported by a reasonable sample of cases. The current data were compiled for all indications which may hinder a more focused conclusion for each procedure. Although the applied inclusion criteria using individual case data reduced the available sample of literature, this methodology allowed age stratification and yielded 50 or more cases in each age group which is a robust sampling for these procedures.

Conclusion

In aggregate, clinical outcomes at short-to-midterms of follow-up are comparable between 4CA and PRC. However, stratification of cases into age groups displays trends that may be clinically relevant. PRC in patients over 45 years

demonstrated significantly greater grip strength recovery compared with patients under 45 years. Further, there is an increased risk of disability based on the DASH score when treating patients under 45 years with 4CA. This indicates the need for setting expectations prior to 4CA in younger adults.

IRB

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Conflict of Interest

G.K. discloses a consultant relationship with Axogen, Trice Medical, and Ortho Circle and is a shareholder in Oxos Medical. J.H., T.K., P.D.V., and O.G. have nothing to disclose.

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